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An Examination of Turnover Rate of Herring on the Spawning Grounds of Scots Bay and German Bank using Tagging Data

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Examen du taux de roulement du hareng dans les frayères de la baie Scots et du banc German à l'aide des données de marquage

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ABSTRACT

A tagging study was undertaken on the spawning grounds of Scots Bay and German Bank to examine the residency time of herring on the grounds during spawning season. Tagging was attempted on as close to a weekly basis as possible, although weather or a lack of fishing activity sometimes prevented this. A total of 8,580 tags were applied to herring from Scots Bay on four occasions and a total of 5,047 tags were applied to herring on German Bank on five occasions. The overall tag return rate for Scots Bay was 4.5%, whereas the return rate from German Bank was only 0.6%. Returns from both spawning grounds indicated that, although the majority of tag returns came from within the first three weeks after tagging, some fish remained on the spawning grounds for up to five to six weeks after tagging. The possibility that some herring remain on the spawning grounds for longer than the previously assumed 10 to 14 day interval has implications for the timing of the repeated acoustic surveys of the spawning grounds used in the 4VWX herring assessment in recent years.

RÉSUMÉ

Une étude de marquage a été entreprise dans les frayères de la baie Scots et du banc German, en vue d'examiner le temps passé dans les frayères par le hareng pendant la période de ponte. On a tenté de procéder au marquage des poissons à toutes les semaines, dans la mesure du possible, mais le mauvais temps ou l'absence d'activité de pêche a parfois rendu la chose impossible. Au total, 8 580 étiquettes ont été apposées à des harengs de la baie Scots à quatre reprises et 5 047, à des harengs du banc German, à cinq occasions. Le taux de récupération des étiquettes dans l'ensemble a été de 4,5 % pour la baie Scots, mais de seulement 0,6 % pour le banc German. À en juger par les retours de harengs des deux frayères, bien que la plupart des étiquettes aient été récupérées au cours des trois premières semaines suivant le marquage, certains poissons sont demeurés dans les frayères jusqu'à cinq ou six semaines après le marquage. La possibilité que certains harengs restent dans les frayères plus longtemps que les 10 à 14 jours présumés antérieurement a des répercussions sur le moment choisi pour les relevés acoustiques répétés dans les frayères qui ont servi à l'évaluation des harengs de 4VWX ces dernières années.

1. INTRODUCTION

The current assessment for herring, *Clupea harengus*, from the Southwest Nova/Bay of Fundy Spawning Component employs repeated acoustic surveys of the spawning grounds (Power *et al.*, 2005). These surveys are required to be separated by at least 10 to 14 days in an attempt to prevent double counting (Power *et al.*, 2002). Knowledge of the length of time that herring remain on the spawning grounds and whether or not they leave immediately after spawning is therefore of great importance to the survey method, particularly for the major spawning grounds of German Bank and Scots Bay.

2. BACKGROUND

The amount of time that herring spend on the spawning grounds and the factors that initiate migration and homing are not clearly defined (Haegele and Schweigert, 1985). Runnstrom (1941) stated that herring move onto the spawning grounds at night and spawn over several weeks, with the oldest fish spawning first. Waves of spawning have been reported in the past (Lambert, 1984, 1987, Hay 1985). Blaxter (1985) stated that it was common for spawning to occur over a period of a few weeks on a given spawning ground. This was supported by Bradford (1991) who found that, with individual populations, spawning is a continuous process throughout the spawning season, although within this there may be single or multiple waves. Spawning waves have been documented for Pacific Herring (*Clupea pallasii*). These spawning waves are separated by roughly 10 to 15 days and later spawners tend to be younger and smaller (Hay, 1985).

Prior to 1998, the calculation of the Spawning Stock Biomass (SSB) for Southwest Nova Scotia herring was based on a VPA tuned using a fall larval herring survey. (Stephenson *et al.*, 1998). Between 1997 and 2004 the SSB calculation was based on the acoustic estimates from regular surveys conducted on the spawning grounds and in 2005 the acoustic estimates were used as an index to tune the VPA (Power *et al.*, 2004, 2005). The time between acoustic surveys and the turnover rate of herring on the spawning grounds are therefore critical since surveys which are too close together may be counting the same fish.

An analysis of the existing data on turnover rates of herring on the German Bank Spawning grounds was made in 2002 (Clark *et al.*, 2002; Appendix C in Power *et al.*, 2002). This included an analysis of the length and maturity data from 1995 to 2001, previous tagging data, fat content and age information. Four recommendations were made:

1. Sampling of herring on the German Bank spawning ground should be continued at the same level of intensity as in 2001.
2. If tagging is to be used as a method of examining turnover rate, the application of tags at a specific interval (weekly) should be instigated on German Bank.
3. There should be increased acoustic effort to document the behaviour, number and size of schools of herring on the spawning grounds.

4. Herring spawning behaviour should be documented using underwater video equipment.

The first of these recommendations has been addressed. Intensive sampling for maturity stage has been conducted since the 2002 fishing season with the results summarized by Melvin *et al.* (2003, 2004) and Power *et al.* (2005). These results were used to assist in the evaluation of turnover timing and inclusion or exclusion of specific acoustic surveys (Power *et al.*, 2005) but did not give clear indications of a consistent turnover rate or the residency time of herring on the spawning grounds. The second of the recommendations is addressed by the tagging study reported in this document.

In March, 2005, concerns were again raised regarding turnover rate at the 4VWX Herring Regional Advisory Process (RAP) Meeting. It was noted that, if acoustic survey estimates were taken as absolute estimates of abundance, then there were inconsistencies between the summed survey estimates and the SSB as calculated by a virtual population analysis. The opinion was expressed that these variations necessitated exploration and that further work was required on turnover rate (Neilson, 2005). In order to address this concern, tagging was conducted in the summer and fall of 2005 on the spawning grounds of Scots Bay and German Bank.

As was reported in Paul (1999) and Power *et al.* (2002), tagging was conducted on spawning fish on German Bank in the past. In 1998 a total of 9,068 spawning herring were tagged and there were 28 within season tag returns from German Bank. Of those 28 returns, eight were caught more than ten days and six were caught more than fourteen days after tagging (Paul, 1999). In 2001 a total of 9,698 spawning herring were tagged on German Bank over a two day period. There were 47 tag returns from the spawning grounds, all within 8 days after tagging but the results were complicated by a large decrease in fishing effort in the second week after tag application.

3. METHODS

In July and August, 2005 the Herring Science Council (HSC), Fundy Weir Fishermen Association (FWFA) and the Maine Department of Marine Resources (DMR) conducted four tagging events in Scots Bay using purse seine vessels. In August and September DFO, HSC, FWFA and DMR conducted five tagging events using purse seine vessels on German Bank. The tagging procedure used was identical for all trips. The crew of the vessels loosely pursed the seine leaving the herring in the water. Herring were then transferred by dip net from the seine to a Xactics tank filled with running sea water. Herring were tagged between the fin rays at the base of the dorsal fin using individually numbered external Hallprint t-bar tags bearing the dual Canada/U.S.A. address as follows:

DFO/SABS NB E5B 2L9
DMR PO 8 W BOOTHBAY Hbr ME 04575

The tags were identical to those used in the FWFA weir herring tagging project (fall 2002 to present) and the DMR herring tagging project (2003 to present). Herring were released back into the water as they were tagged and any fish that appeared unhealthy were not tagged.

A random length frequency sample of 100 to 200 herring was collected from each tagging set and a sub-sample was frozen for detailed laboratory analysis of age, sex and maturity.

Tags were returned to the St. Andrews Biological Station where the information was entered into a database and the data were analysed. Names of people who returned tags were entered into an annual draw for \$1,000, funded by industry.

As part of the ongoing weir herring tagging project, a protocol already existed in many processing plants to encourage individuals to return tags and posters were distributed to these plants. A press release about this project was also prepared and articles appeared in local newspapers such as the Sou'wester and The Saint Croix Courier.

4. RESULTS

4.1 Scots Bay

A total of 5,047 tags were applied in Scots Bay on four separate occasions (Table 1). The weekly landings for Scots Bay in relation to the tagging events are shown in Table 2 and Figure 1. There was fishing after all tagging trips, although the landings dropped considerably after the last tagging event and the fishery concluded on September 9, only two weeks after the final tagging trip (Figure 1).

The maturity data from samples collected during the tagging events on Scots Bay are shown in Figure 2. Samples collected on August 7, 15 and 24 contained primarily stage 6 (spawning) herring (between 64 and 77%). The percentage of stage 6 herring was much lower (9%) in the July 28 sample in which 64% were stage 7 (spent). The high percentage of stage 7 fish was unexpected since it has been proposed in the past that herring leave the spawning grounds immediately after spawning. The maturity data from all samples collected on Scots Bay over the course of the entire fishery are shown in Figure 3 and length frequencies are shown in Figure 4.

To date 228 tags have been returned (Table 3), a tag return rate of 4.5%. To avoid a bias from fish recaptured immediately after tagging, the tag returns from the first 2 days after tagging were removed. When this was done the number of tag returns decreased to 151, a tag return rate of 3%. The majority of the returns that were caught within 2 days were from the tagging event on August 15 (57 tag returns).

In this project tags were applied at close to weekly intervals. The rationale behind this was that if fish tagged in the first week were not caught on the spawning ground more than seven days after the first tagging event, but fish tagged the following week were being caught, then there would be a stronger basis for concluding that the fish from week 1 had left the spawning ground. In Table 4 the raw tag return data are presented by week. The same data were adjusted by the landings (Table 5 and 6, Figure 5 and 6) to allow comparisons to be made between weeks.

A turnover rate of between 7 to 14 days has been suggested in the past based on anecdotal information from fishers and maturity information. Tag return data is presented in this context in Tables 7 and 8 and Figure 7. It should be noted that there was decreased fishing effort after the final tagging event. Also fishing ended 16 days after the final tagging event and thus, no tag returns are possible after this 16 day period.

During the data analysis, it was noted that there might be differences in tag return rate depending on where and how the fish were processed. The percentage of Scots Bay fish bought and of tag returns by buyer is shown in Figure 8. The major buyers of Scots Bay fish appear to be detecting and returning tags.

Quantifying Turnover Rate in Scots Bay

There were sufficient tag returns from Scots Bay to compare the proportion of fish that remained on the spawning grounds over time. The tag returns from Scots Bay were adjusted by landings (Table 9) and then standardized in the following manner:

n = number of tag returns adjusted by the landings

n_{wi} = the number returns from a given tagging event w , where $i=1$ is the first week after tagging, $i=2$ is the second week etc

n_{w1} = the number of tag returns from the first week after tagging for tagging event w . This is assumed to be the number of tag returns you would get if all the fish are still present on the spawning grounds.

$\frac{N_{wi}}{n_{w1}}$ = the proportion of fish in week i from tagging event w still present on the spawning grounds (Table 10).

$\frac{N_{wi}}{n_{w1}}$ This standardizes so that the proportions from different tagging dates can be compared and averaged (Table 11, Figures 9 and 10).

$$\sum \frac{N_{wi}}{n_{w1}}$$

There was a large amount of variation in the proportion of tagged fish present in any given week; this is clearly demonstrated by the high standard errors. Also, as was noted above, there was decreased fishing effort after the August 24 tagging and fishing ended two weeks later so there was no information on long term tag

returns from this event or for tag returns more than 3 weeks after the August 15 tagging event.

Tag Returns from Areas Other than Scots Bay

A total of 63 tag returns (42%) came from areas other than Scots Bay (Table 4). Of these, 40 tags (26%) came from the New Brunswick weirs, some within the first few days after tagging. Fish tagged in the Scots Bay weirs ranged from 22 to 31.5 cm in length and were predominantly in spawning or post-spawning condition (Figures 2 to 4). The length frequency and maturity information for the samples collected from the New Brunswick weirs shows that fish of the same size as those in Scots Bay were present in the weirs, as were spawning and post-spawning fish (Figures 11 and 12).

Small numbers of tag returns also came from other areas, including the Nova Scotia weirs, the Long Island Shore, Northeast Bank, Northwest Ledge and German Bank (Table 4 and 5, Figure 6).

4.2 German Bank

A total of 8,580 tags were applied to herring on the spawning grounds of German Bank on five separate occasions between August 30 and October 5, 2006 (Table 12). The weekly landings for German Bank in relation to the tagging events are shown in Table 13 and Figure 13. There were no tag returns from the September 21 tagging event but correspondingly, there were no landings from German Bank between September 24 and October 2. The lack of landings in this time period leaves a hole in the data. The German Bank fishery ended on October 13, only eight days after the last tag applications on October 4 (Figure 13).

The maturity data from samples collected during the tagging events on German Bank are shown in Figure 14. For all but the first tagging event, the samples contained predominantly spawning stage 6 herring (between 89% and 98% of the samples). In the sample taken on August 30, 88% of the herring are stage 5 (hard roe). The maturity and length data from all the samples collected from the German Bank fishery from August 30 onwards are shown in Figures 15 and 16. After August 30 samples contained mostly stage 6 fish and the length frequency mode was around 27 cm.

To date 56 tags have been returned (Table 14), a tag return rate of only 0.7%. Most of these tag returns (42) came from the German Bank fishery. The tag returns from the first 2 days after tagging were removed to avoid a bias from fish recaptured immediately after tagging. This had little effect on the tag return data. The overall number of tag returns decreased to 52 (38 from German Bank), a tag return rate of 0.6%.

As with the Scots Bay experiment, it was proposed that tags be applied at weekly intervals for this project. This was accomplished for the first four tagging events, but the lack of fishing between September 24 and October 2 precluded tagging

during that week. In Table 15 the raw tag return data are presented by week. The same data were adjusted by the landings (Table 16 and 17, Figure 17 and 18) to allow comparisons to be made between weeks.

Tag return data are presented in Tables 18 and 19 and Figure 19 in the context of the suggested turnover rate of between 7 to 14 days. The lack of fishing between September 24 and October 2 and the after October 13 precludes long term tag returns from the last two tagging events.

The tag return rate of 0.6% is considered low. The percentage of Scots Bay fish bought and of tag returns by buyer is shown in Figure 20. Tag returns from the German Bank fishery have been received from only three plants which bought only about 40% of the German Bank fish. The remaining plants, which bought about 60% of the German Bank fish, did not return tags.

Tag Returns from Areas Other than German Bank

There were very few tag returns from areas other than German Bank. Six tags were returned from the Grand Manan area seiner fishery, 2 from the New Brunswick weirs, and 1 from The Patch on the Offshore Scotian Shelf (Table 15).

5. DISCUSSION

In the past one of the reasons that the interpretation of tagging data for turnover rates was difficult was because it was confounded by changes in effort. In this project, tags were applied at weekly intervals in attempt to avoid this issue. As was stated in Appendix C of Power *et al.*, (2002):

"If fish tagged in week 1 are not caught on the spawning ground more than seven days after the first tagging event, but fish tagged the following week are being caught and returned, then there would be a stronger basis for concluding that the fish from week 1 had left the spawning ground."

On both Scots and German Bank, the majority of tag returns came from the first 3 weeks after tagging. However some fish remained on the spawning grounds for up to five to six weeks after tagging (Tables 6, 8, 17 and 19, Figures 5, 7, 17 and 19). For the first three tagging events in Scots Bay tagged fish were present on the spawning grounds for at least three weeks after tagging and, in one case, five weeks after tagging. The last tagging event was too late in the season to determine if fish were still around in Scots Bay after two weeks. On German Bank tagged fish were caught five and six weeks after tagging. If acoustic surveys had been conducted at 10 ten day intervals, then some of the fish would clearly have surveyed at least twice.

The attempt to quantify the turnover rate on Scots Bay (Tables 9 to 11, Figures 9 and 10) shows a huge amount of variability. This likely indicates that the residency time of fish on the spawning grounds is variable and therefore hard to quantify and

predict, making it difficult to plan acoustic surveys at fixed intervals, without the possibility of counting the same fish twice.

The tag return rate from German Bank was very low (0.6%), but this was comparable to the experiments conducted in 1998 (0.3%) and 2001 (0.5%)(Paul, 1998, Clark *et al.*, 2002). The results from the 2005 German Bank tagging experiment were similar to those of 1998 when 20% of the tag returns were from more than two weeks after the tagging event (Paul, 1999).

The data presented in Figures 8 and 20, show that some fish plants are not detecting and returning tags. It appears that the major processors of Scots Bay fish are finding and returning tags, but there were no tag returns from some of the major fish processors of German Bank fish. Tags are often missed in fish that are processed for bait, but tags should be detectable on large spawning fish that are processed for human consumption. The tagging projects have been well advertised with visits to the fish plants, media articles and the distribution of posters but this result indicates that it is necessary to further improve this advertising. For this sort of project to work in the future, plants need to set up their own procedures for tag returns so that workers are encouraged to detect and return the tags. An incentive of a small tag reward for each of the major processors might also be considered in future tagging project planning.

There appears to be an affinity between fish tagged in Scots Bay and the New Brunswick weirs. A total of 26% of the Scots Bay tag returns came from the New Brunswick weirs, some within the first few days after tagging. The maturity and length frequency information from the weir fishery shows that there are large fish in pre- and post-spawning condition in the weirs, which is consistent with the tagging data. As part of the New Brunswick Weir Herring Tagging Project that was being conducted concurrent to this experiment, 51 tags that were applied to fish in New Brunswick weirs have been returned from the Scots Bay roe fishery. Of these tags, more than fifty percent were from fish tagged in weirs from the Bliss Islands, coastal mainland and West Isles area. Under the current management scheme, fish from the New Brunswick weirs are considered to be predominantly juveniles (mostly ages 2 and 3) from NAFO Subarea 5 (USA) spawning components and these fish have therefore been excluded from the NAFO area 4WX quota (Power *et al.*, 2005). This assumption is challenged by the apparent connection between the Scots Bay spawning grounds and the New Brunswick weirs.

6. CONCLUSIONS

Tagging of herring in Scots Bay and on German Bank was conducted in 2005 in order to examine the turnover rate of herring on these spawning grounds. Knowledge of the turnover rate is critical for the timing between acoustic surveys since surveys which are too close together count the same fish. Based on the results of the tagging experiment, the following conclusions can be drawn:

- Some tagged herring remain on the spawning grounds for at least 3 weeks after tagging, and in some cases, up to five to six weeks after tagging. As a result, acoustic surveys that are spaced at two week intervals are surveying some of the same fish.
- The residency time of herring on the spawning grounds appears to be extremely variable.
- There appears to be an affinity between the fish tagged in Scots Bay and the New Brunswick weirs.
- For a project like this to be fully successful, tag returns are necessary from all the major fish processors.

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8. TABLES

Table 1. Application of Tags on Scots Bay, July and August 2005.

Date of Application	# Tags Applied
28/07/2005	1,332
07/08/2005	653
15/08/2005	1,662
24/08/2005	1,400
Total	5,047

Table 2. Weekly landings from Scots Bay after tagging commenced.

Date	Landings (t)
Jul 28 to Aug 6	614
Aug 7 to 14	1,169
Aug 15 to 23	1,960
Aug 24 to 30	1,613
Aug 31 to Sep 6	422
Sep 7 to 13	174
Total	5,952

Table 3. Tag returns from Scots Bay tagging experiment.

Application Date	Return Location	Total No. of Tags	No. of Tags > 2 days at large
28/07/2005	Scots Bay	5	5
	NB Weir	11	11
	NS Weir	1	1
	NE Bank	2	2
	NW Ledge	1	1
	Unknown	8	7
07/08/2005	Scots Bay	8	5
	NB Weir	15	15
	NW Ledge	1	1
	Unknown	1	1
15/08/2005	Scots Bay	81	24
	German Bank	1	1
	Long Island Shore	1	1
	NB Weir	5	5
	Unknown	2	1
24/08/2005	Scots Bay	58	44
	NB Weir	9	9
	NS Shore	4	4
	Unknown	14	13
Total Number of Returns		228	151

Table 4. Unadjusted Scots Bay tag returns by week. Tags caught <3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	July 28 to Aug 6	Aug 7 to Aug 14	Aug 15 to Aug 23	Aug 24 to Aug 30	Aug 31 to Sept 6	Sept 7 to Sept 13	Sept 14 to 20	Sept 21 to 27	Sept 28 to Oct 4	Unknown	Total
28/07/2005	1332	Scots Bay	1		1	2		1					5
		NB Weir		3	1		2	2	1	2			11
		NS Weir			1								1
		NE Bank	2										2
		NW Ledge									1		1
		Unknown	4	3									7
07/08/2005	653	Scots Bay		1	2	1						1	5
		NB Weir		10	4						1		15
		NW Ledge							1				1
		Unknown		1									1
15/08/2005	1662	Scots Bay			5	19							24
		German Bank				1							1
		Long Island Shore							1				1
		NB Weir			2	3							5
		Unknown			1								1
24/08/2005	1400	Scots Bay				25	19						44
		NB Weir				8			1				9
		Long Island Shore					1	2	1				4
		Unknown				12	1						13
Total	5047		7	18	17	71	23	5	5	2	2	1	151

Table 5. Adjusted Scots Bay tag returns by week for all tag return areas (No. of tags per 1,000t landed from each area). Tags caught <3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	July 28 to Aug 6	Aug 7 to Aug 14	Aug 15 to Aug 23	Aug 24 to Aug 30	Aug 31 to Sept 6	Sept 7 to Sept 13	Sept 14 to 20	Sept 21 to 27	Sept 28 to Oct 4	Total
28/07/2005	1332	Scots Bay	1.6		0.5	1.2		5.7				9.1
		NB Weir		1.3	0.4		1.5	1.7	1.5	4.5		11.0
		NS Weir			0.4							0.4
		NE Bank	3.9									3.9
		NW Ledge									5.1	5.1
07/08/2005	653	Scots Bay		0.9	1.0	0.6						2.5
		NB Weir		4.4	1.8						1.6	7.8
		NW Ledge							34.5			34.5
15/08/2005	1662	Scots Bay			2.6	11.8						14.3
		German Bank				0.9						0.9
		Long Island Shore							2.0			2.0
		NB Weir			0.9	3.2						4.1
24/08/2005	1400	Scots Bay				15.5	45.0					60.5
		NB Weir				8.5			1.5			10.1
		Long Island Shore					12.3	10.8	2.0			25.1
Total	5047		5.5	6.6	7.6	41.8	58.9	18.2	41.5	4.6	6.6	191.2

Table 6. Scots Bay adjusted tag returns (No. of tags per 1,000t landed from Scots Bay) by week with tags caught less than 3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	July 28 to Aug 6	Aug 7 to Aug 14	Aug 15 to Aug 23	Aug 24 to Aug 30	Aug 31 to Sept 6	Sept 7 to Sept 13	Total
28/07/2005	1332	Scots Bay	2		1	1		6	9
07/08/2005	653	Scots Bay		1	1	1			2
15/08/2005	1662	Scots Bay			3	12			14
24/08/2005	1400	Scots Bay				15	45		61
Total	5047		2	1	4	29	45	6	86

Table 7. Scots Bay tag returns by time interval after tagging. Tags returned less than 3 days after tagging were removed from this table.

Application Date	No. of Tags Applied	Return Location	# Tags < 7 days	# Tags ≥7 and <10 days	# Tags ≥10 and <14 days	# Tags ≥14 and < 21 days	# Tags ≥ 21 days	Unknown Return Date	Total
28/07/2005	1332	Scots Bay	1			1	3		5
		NB Weir				3	8		11
		NS Weir					1		1
		NE Bank	2						2
		NW Ledge					1		1
		Unknown	4		3				7
07/08/2005	653	Scots Bay	1		2	1		1	5
		NB Weir	10	4			1		15
		NW Ledge					1		1
		Unknown	1						1
15/08/2005	1662	Scots Bay	4	4	11	5			24
		German Bank				1			1
		Long Island Shore					1		1
		NB Weir	1	1	3				5
		Unknown		1					1
24/08/2005	1400	Scots Bay	25	18	1				44
		NB Weir	8				1		9
		Long Island Shore		1		2	1		4
		Unknown	12	1					13
Total	5047		69	30	20	13	18	1	151

Table 8. Tag returns from Scots Bay by time interval after tagging. Tags returned less than 3 days after tagging were removed from this table.

Application Date	No. of Tags Applied	Return Location	# Tags < 7 days	# Tags ≥7 and <10 days	# Tags ≥10 and <14 days	# Tags ≥14 and < 21 days	# Tags ≥ 21 days	Unknown Return Date	Total
28/07/2005	1332	Scots Bay	1			1	3		5
07/08/2005	653	Scots Bay	1		2	1		1	5
15/08/2005	1662	Scots Bay	4	4	11	5			24
24/08/2005	1400	Scots Bay	25	18	1				44
Total	5047		31						78

Table 9. The number of Scots Bay tag returns per 1,000t landed by tagging event (w) and by the number of weeks after tagging (i).

Tagging Event (w)	Number of Weeks after Tagging (i)					Total
	1	2	3	4	5	
28-Jul-05	1.63	0.00	0.51	1.24	0.00	3.38
07-Aug-05		6.17	1.02	0.62	0.00	7.81
15-Aug-05			31.63	11.78	0.00	43.41
24-Aug-05				24.18	45.02	69.20
Total	1.63	6.17	33.16	37.82	45.02	123.81

Table 10. Scots Bay tag returns as a proportion of the returns from week 1 of each tagging event (n_{wi}/n_{w1}).

Tagging Event (w)	Number of Weeks after Tagging (i)					Total
	1	2	3	4	5	
28-Jul-05	1.00	0	0.31	0.76	0	2.07
07-Aug-05	1.00	0.17	0.10	0		1.27
15-Aug-05	1.00	0.37	0			1.37
24-Aug-05	1.00	1.86				2.86
Total	4.00	2.40	0.41	0.76	0.00	7.57

Table 11. Data for Scots Bay from Table 3 standardized by the totals $[(n_{wi}/n_{w1})/(\sum(n_{wi}/n_{w1}))]$.

Tagging Event (w)	Number of Weeks after Tagging (i)				
	1	2	3	4	5
28-Jul-05	48%	0%	15%	37%	0%
07-Aug-05	79%	13%	8%	0%	
15-Aug-05	73%	27%	0%		
24-Aug-05	35%	65%			
Mean	59%	26%	8%	18%	0%
SE	10%	14%	4%	19%	

Table 12. Application of Tags on German Bank, August and September, 2005.

Date of Application	# Tags Applied
30-Aug-05	1,061
06-Sep-05	3,548
13-Sep-05	1,735
21-Sep-05	1,258
05-Oct-05	978
Total No. Applied	8,580

Table 13. Weekly landings from German Bank after tagging commenced.

Date	Landings (t)
Aug 30-Sep 5	837
Sep 6 to 12	2,715
Sep 13 to 19	2,584
Sep 20 to 26	1,052
Sep 27-Oct 3	1,091
Oct 4 to 10	1,681
Oct 11 to 17	1,146
Total	11,106

Table 14. Tag returns from German Bank Tagging Experiment

Application Date	Return Location	Total No. of Tags	No. of Tags > 2 days at large
30-Aug-05	German Bank	6	6
6-Sep-05	German Bank	19	18
	Grand Manan	1	1
	NB Weir	2	2
	Unknown	3	3
13-Sep-05	German Bank	3	1
	The Patch	1	1
21-Sep-05			0
5-Oct-05	German Bank	14	13
	Grand Manan	5	5
	Unknown	2	2
Total Number of Returns		56	52

Table 15. Unadjusted German Bank tag returns by week. Tags caught <3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	Aug 30 to Sept 5	Sep 6 to Sept 12	Sep 13 to Sep 19	Sep 20 to Sep 26	Sep 27 to Oct 3	Oct 4 to Oct 10	Oct 11 to Oct 17	Total
30-Aug-05	1061	German Bank		1	3	1			1	6
06-Sep-05	3548	German Bank		4	8	2		2	2	18
		NB Weir			1			1		2
		Grand Manan							1	1
		Unknown			2	1				3
13-Sep-05	1735	German Bank			1					1
		The Patch							1 (Nov 26)	1
21-Sep-05	1258									0
05-Oct-05	978	German Bank							13	13
		Grand Manan							5	5
		Unknown							2	2
Total	8580		0	5	15	4	0	3	25	52

Table 16. Adjusted German Bank tag returns by week for all tag return areas (No. of tags per 1,000t landed from each area). Tags caught <3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	Aug 30 to Sept 5	Sep 6 to Sept 12	Sep 13 to Sep 19	Sep 20 to Sep 26	Sep 27 to Oct 3	Oct 4 to Oct 10	Oct 11 to Oct 17	Total
30-Aug-05	1061	German Bank		0.4	1.2	1.0			0.9	3.4
06-Sep-05	3548	German Bank		1.5	3.1	1.9		1.2	1.7	9.4
		NB Weir			1.7			3.3		5.0
		Grand Manan							11.4	11.4
13-Sep-05	1735	German Bank			0.4					0.4
		The Patch							2.8 (Nov 26)	2.8
21-Sep-05	1258									0
05-Oct-05	978	German Bank							11.3	11.3
		Grand Manan							56.8	56.8
Total	8580		0	1.8	6.4	2.9	0.0	4.5	87.2	100.5

Table 17. German Bank adjusted tag returns by week (No. of tags per 1,000t landed from German Bank) with tags caught less than 3 days after tagging removed.

Application Date	No. of Tags Applied	Return Location	Aug 30 to Sept 5	Sep 6 to Sept 12	Sep 13 to Sept 19	Sep 20 to Sept 26	Sep 27 to Oct 3	Oct 4 to Oct 10	Oct 11 to Oct 17	Total
30-Aug-05	1,061	German Bank		0.4	1.2	1.0			0.9	3.4
06-Sep-05	3,548	German Bank		1.5	3.1	1.9		1.2	1.7	9.4
13-Sep-05	1,735	German Bank			0.4					0.4
21-Sep-05	1,258									0
05-Oct-05	978	German Bank							11.3	11.3
Total	8,580		0.0	1.8	4.6	2.9	0.0	1.2	14.0	24.5

Table 18. German Bank tag returns by time interval after tagging. Tags returned less than 3 days after tagging were removed from this table.

Application Date	No. of Tags Applied	Return Location	# Tags < 7 days	# Tags ≥7 and <10 days	# Tags ≥10 and <14 days	# Tags ≥14 and < 21 days	# Tags ≥ 21 days	Total
30-Aug-05	1,061	German Bank			1	3	2	6
06-Sep-05	3,548	German Bank	4	5	3	2	4	18
		Bliss Islands			1			1
		Grand Manan					1	1
		Wolves					1	1
		Unknown		1	1	1		3
13-Sep-05	1,735	German Bank	1					1
		The Patch					1	1
21-Sep-05	1,258							0
05-Oct-05	978	German Bank	12	1				13
		Grand Manan	1	3				4
		Seal Island	1					1
		Unknown	2					2
Total	8,580		21	10	6	6	9	52

Table 19. Tag returns from German Bank by time interval after tagging. Tags returned less than 3 days after tagging were removed from this table.

Application Date	No. of Tags Applied	Return Location	# Tags < 7 days	# Tags ≥7 and <10 days	# Tags ≥10 and <14 days	# Tags ≥14 and < 21 days	# Tags ≥ 21 days	Total
30-Aug-05	1,061	German Bank			1	3	2	6
06-Sep-05	3,548	German Bank	4	5	3	2	4	18
13-Sep-05	1,735	German Bank	1					1
21-Sep-05	1,258							0
05-Oct-05	978	German Bank	12	1				13
Total	8,580		17	6	4	5	6	38

9. Figures

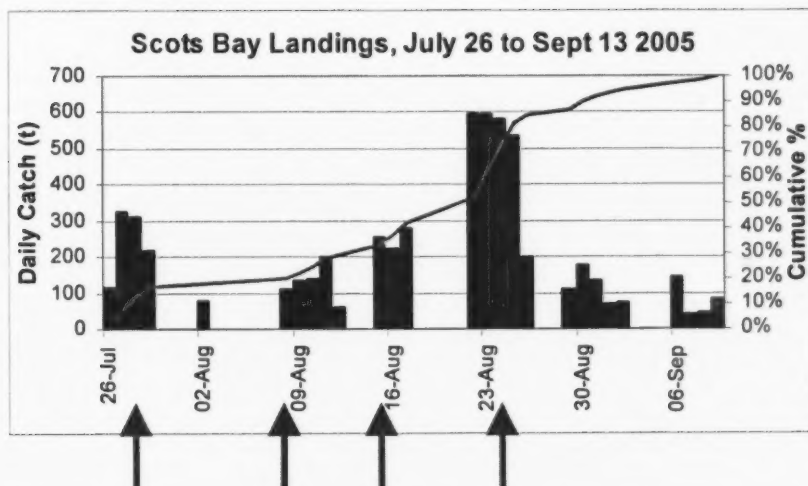


Figure 1. Daily landings from Scots Bay after tagging commenced. Arrows indicate tagging dates.

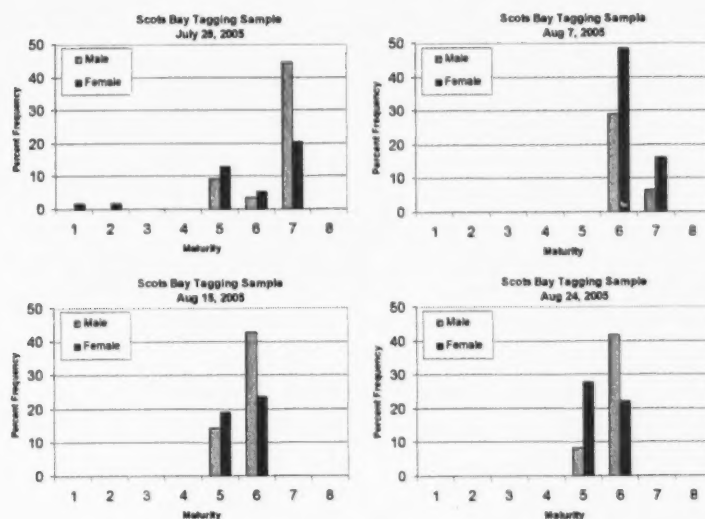


Figure 2. Maturity stages from samples taken during tagging in Scots Bay.

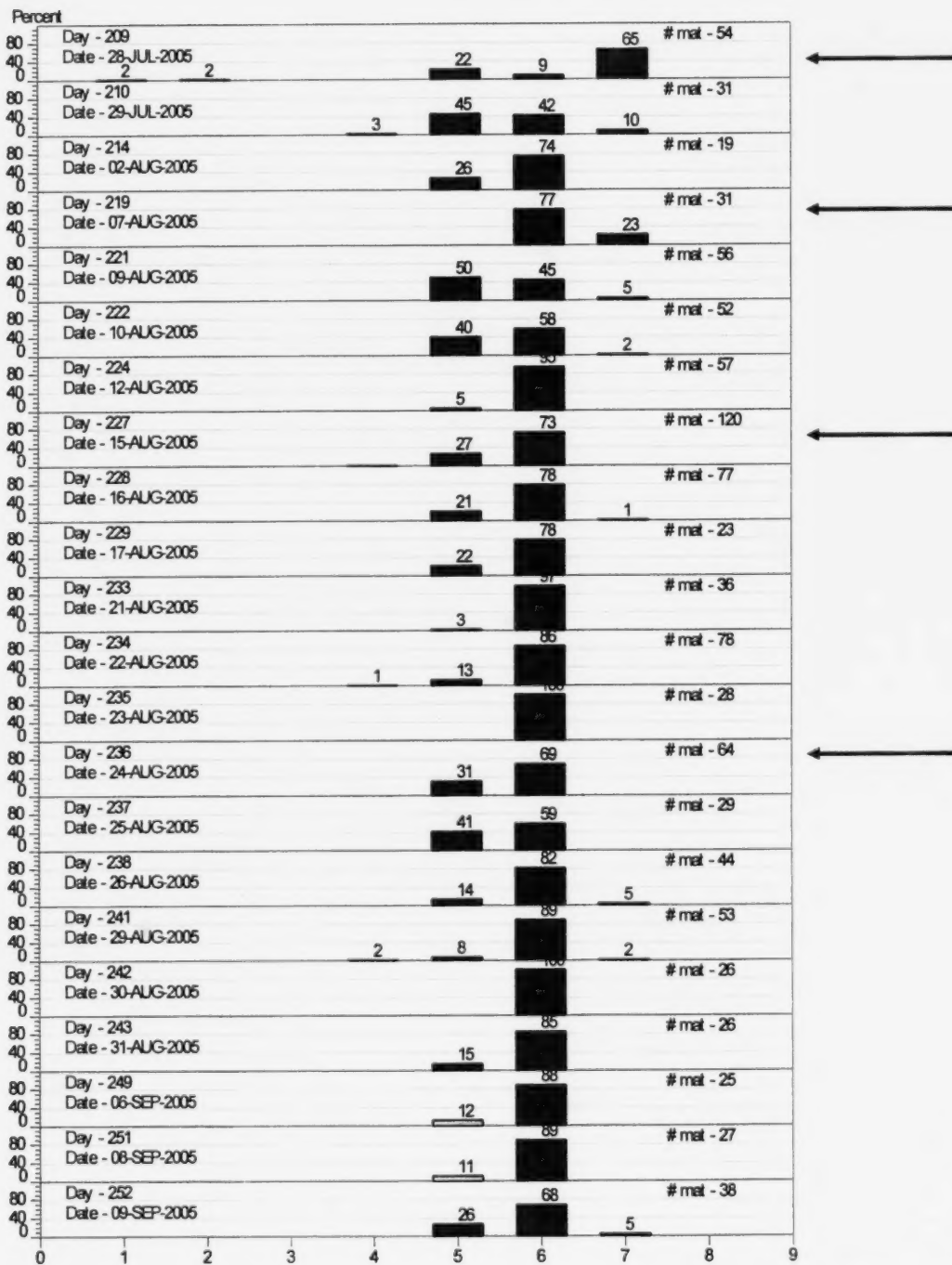


Figure 3. Scots Bay 2005 daily maturity samples. Arrows indicate tagging events.

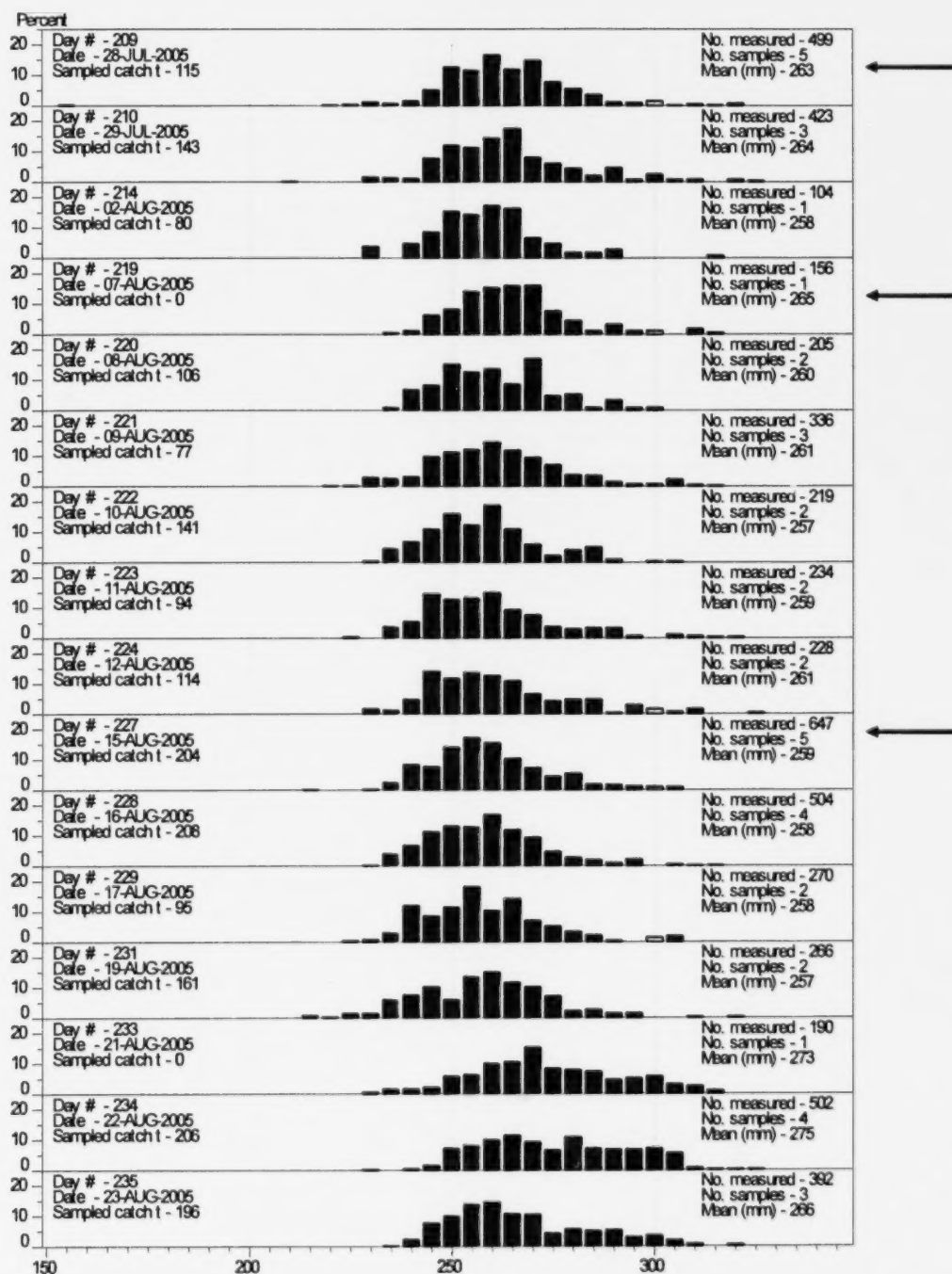


Figure 4. Scots Bay daily length frequencies. Arrows indicate tagging events.

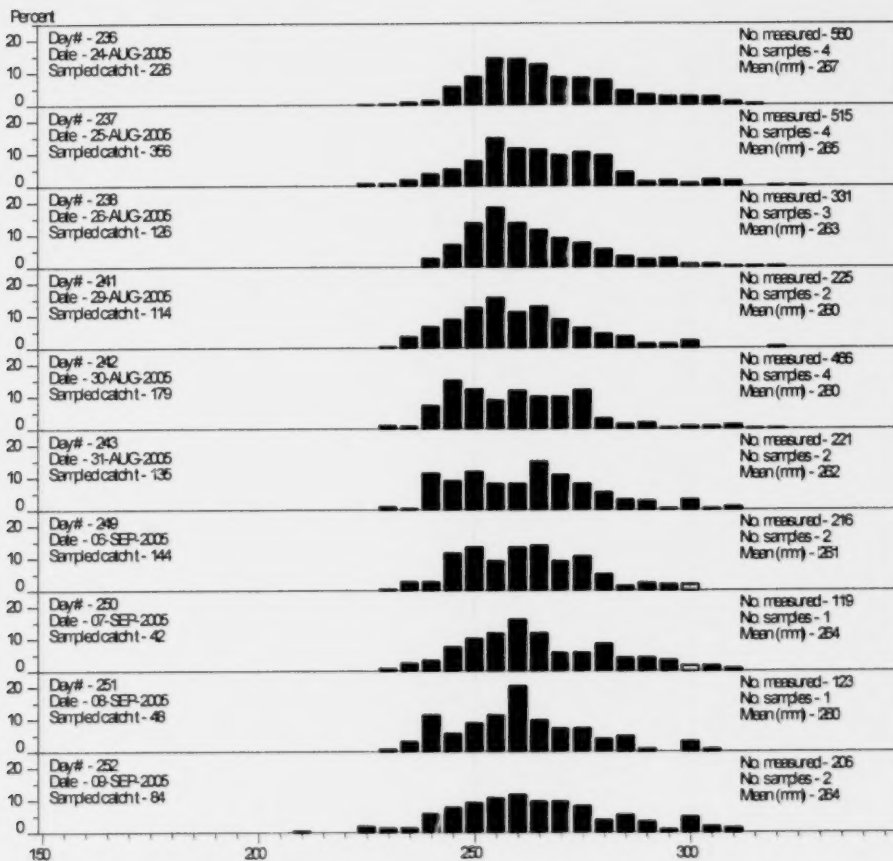


Figure 4 (cont). Scots Bay daily length frequencies. Arrows indicate tagging events.

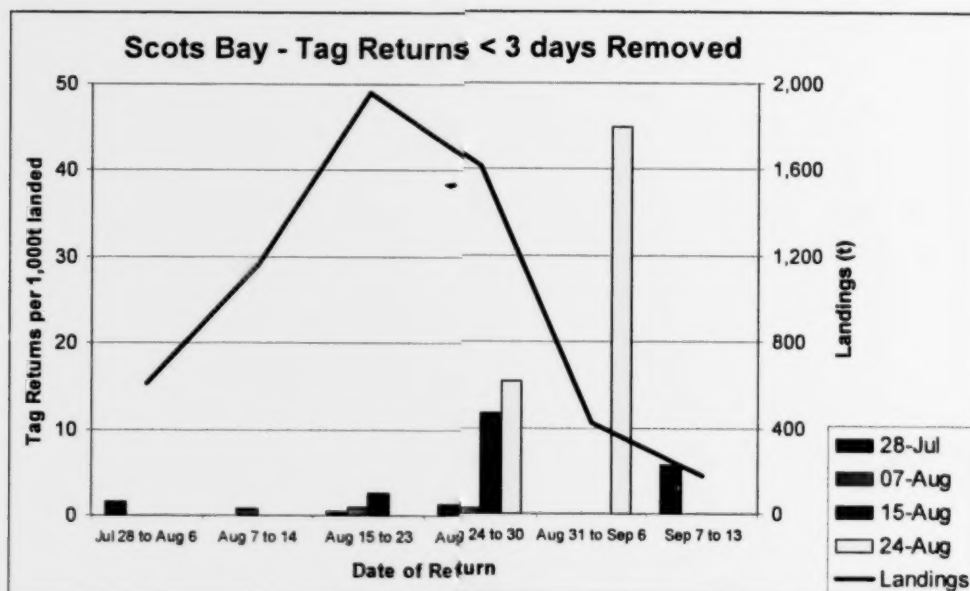


Figure 5. Adjusted tag returns from Scots Bay by week (data from Table 6 presented graphically). All tags caught <3 days after tagging were removed.

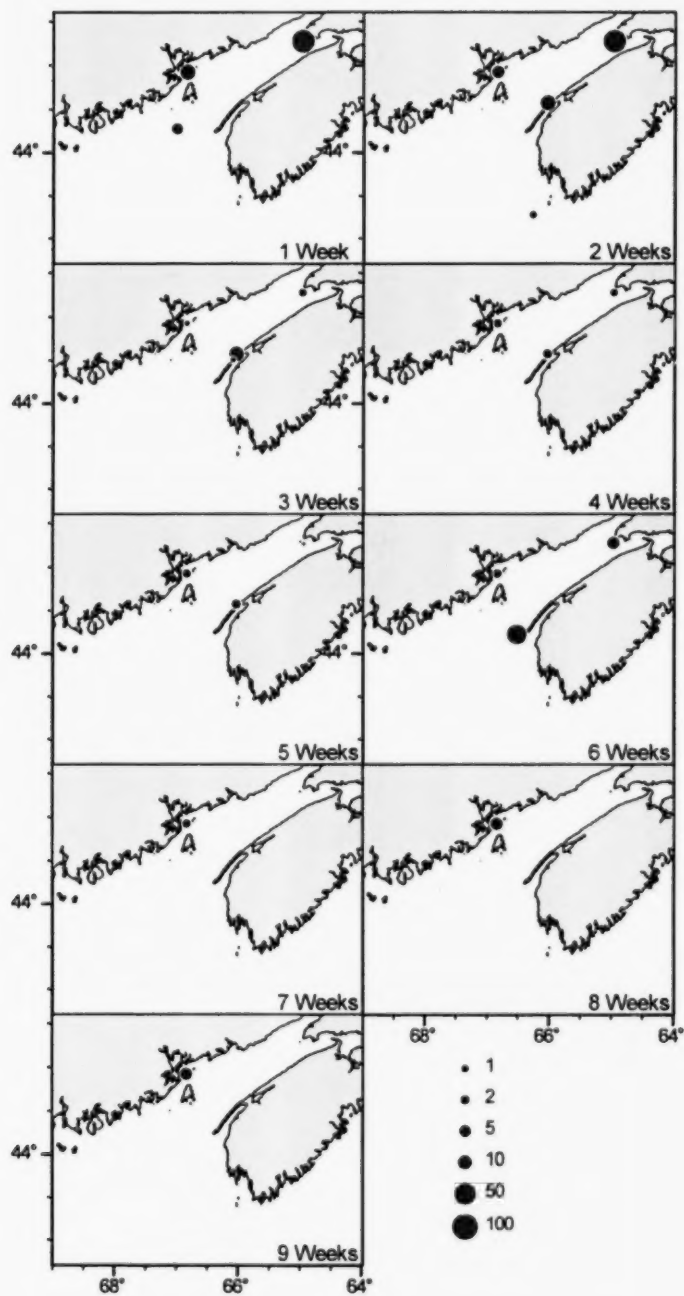


Figure 6. Adjusted tag returns by number of weeks after each tagging event from all areas for fish tagged in Scots Bay.

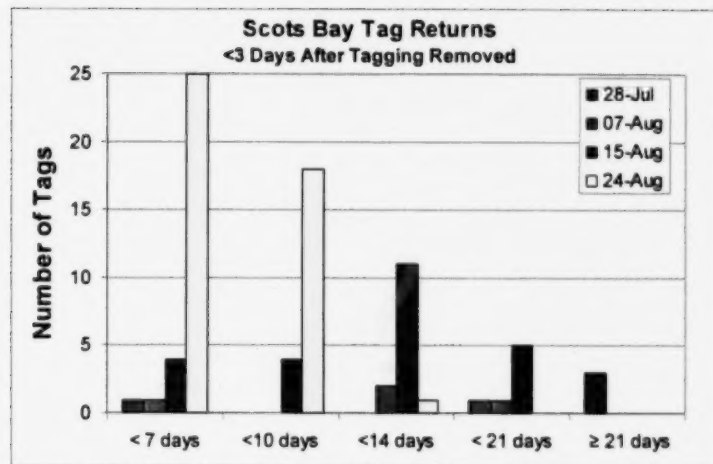


Figure 7. Tag returns from Scots Bay. All tags caught <3 days after tagging were removed.
 (Data from Table 8 presented graphically)

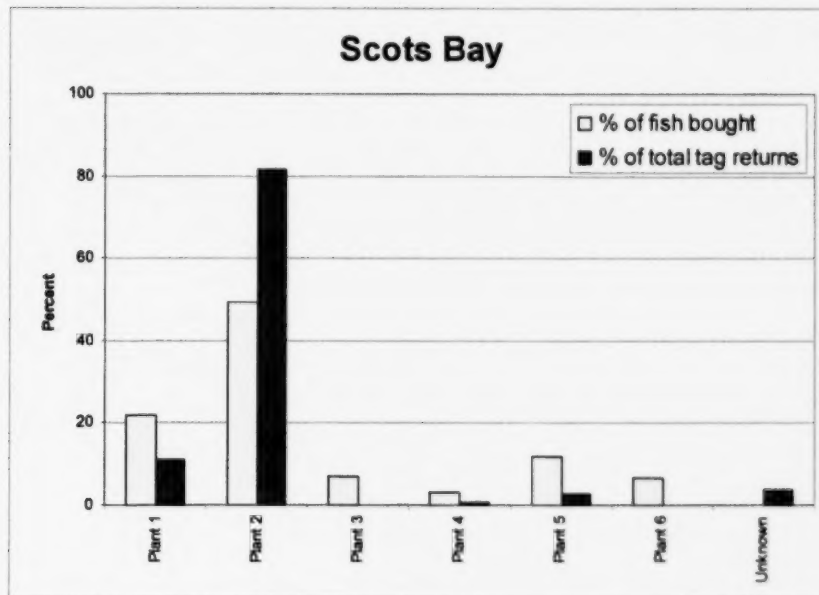


Figure 8: Percent of Scots Bay fish bought by processor compared to the percent of tag returns received from each plant.

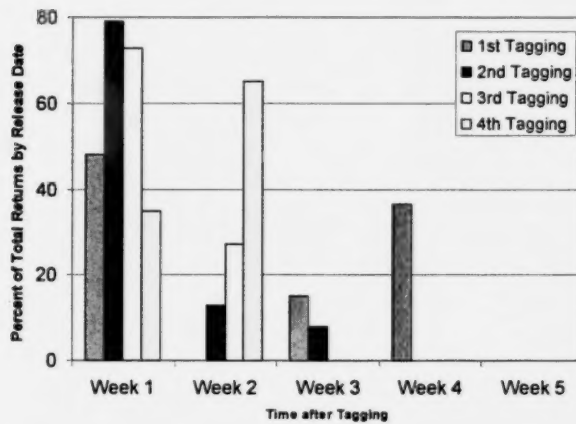


Figure 9. Scots Bay tag returns as a proportion of the returns from week 1 of each tagging event. (Data from Table 11 presented graphically).

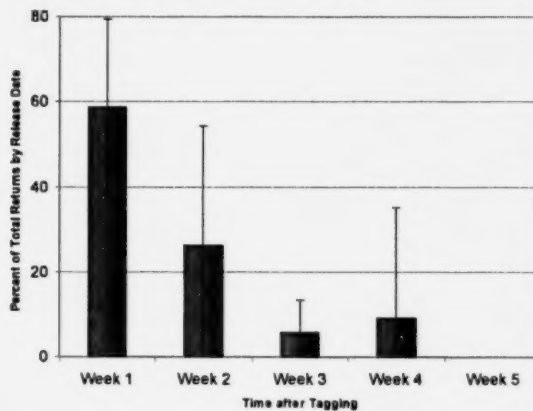


Figure 10. Scots Bay average tag returns (with standard deviations) as a proportion of the returns from week 1 for all tagging events. (Data from Table 11 presented graphically).

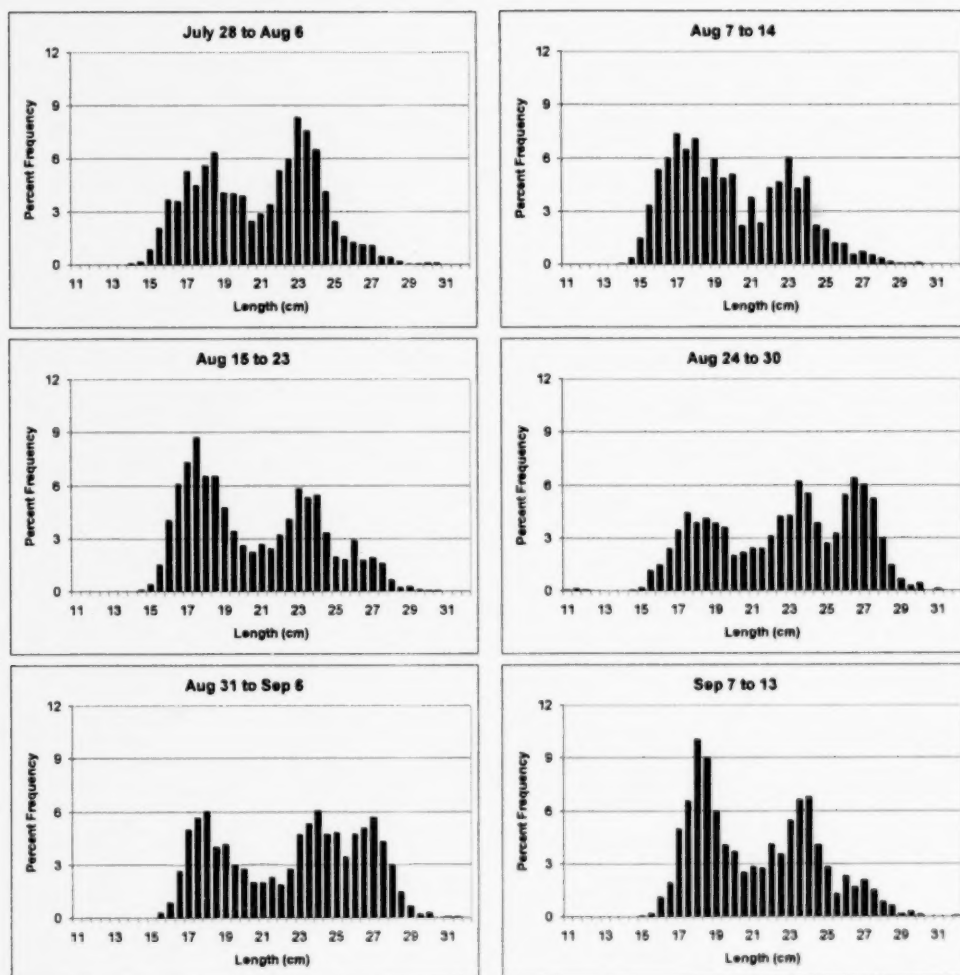


Figure 11. Length frequencies of samples collected from the New Brunswick weirs in the six weeks after the beginning of the Scots Bay tagging experiment.

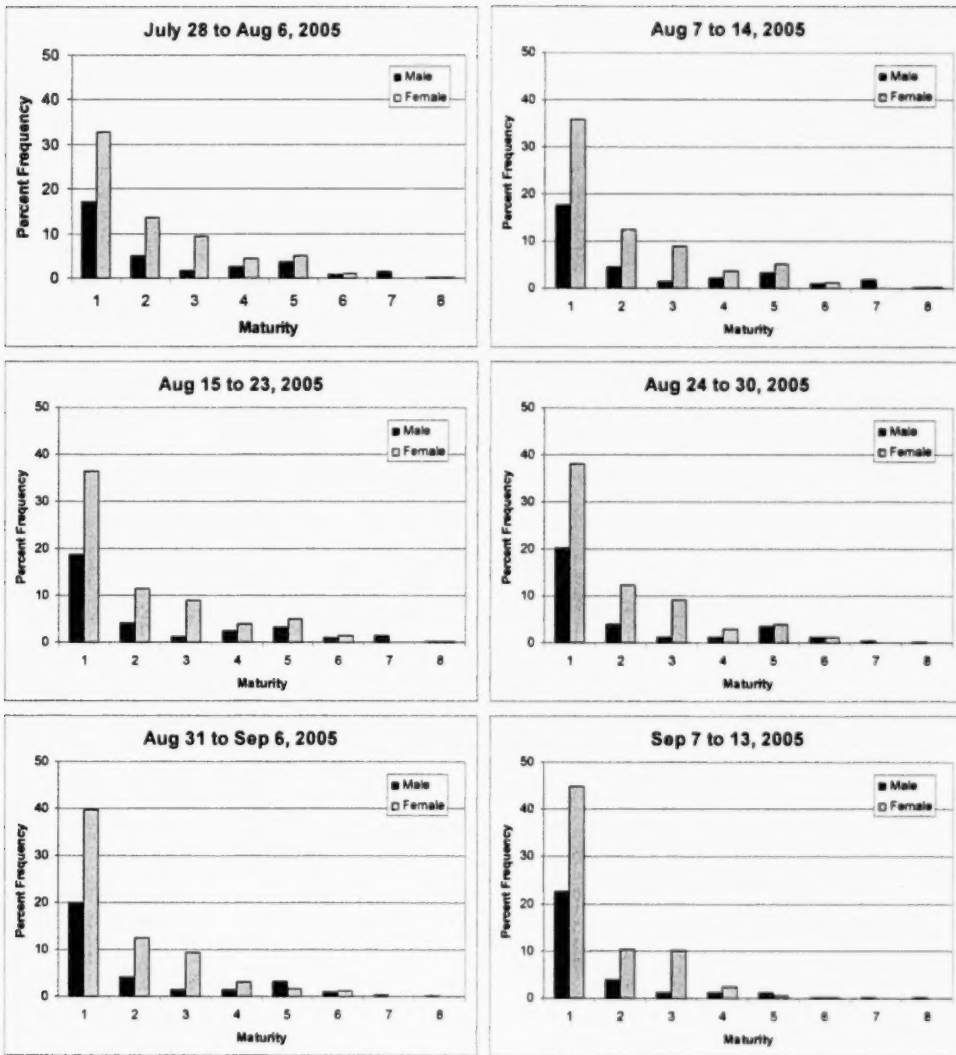


Figure 12. Percent maturity by sex of samples collected from the New Brunswick weirs in the six weeks after the beginning of the Scots Bay tagging experiment.

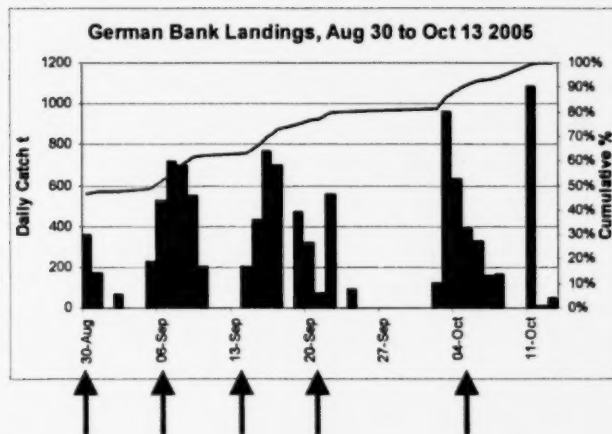


Figure 13. Daily landings from German Bank after tagging commenced. Arrows indicate tagging dates.

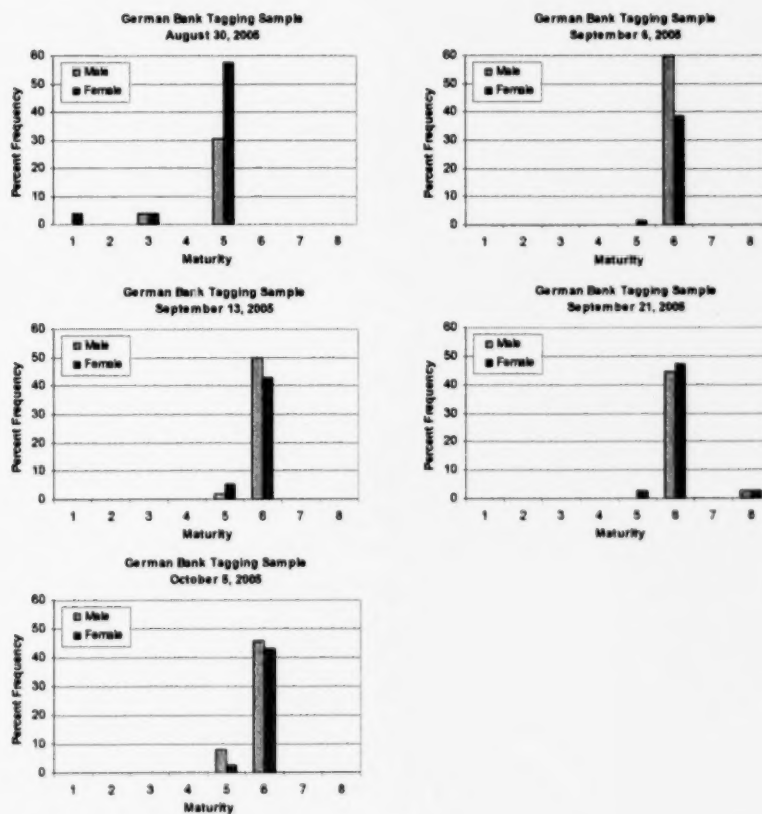


Figure 14. Maturity stages from samples taken during tagging on German Bank.

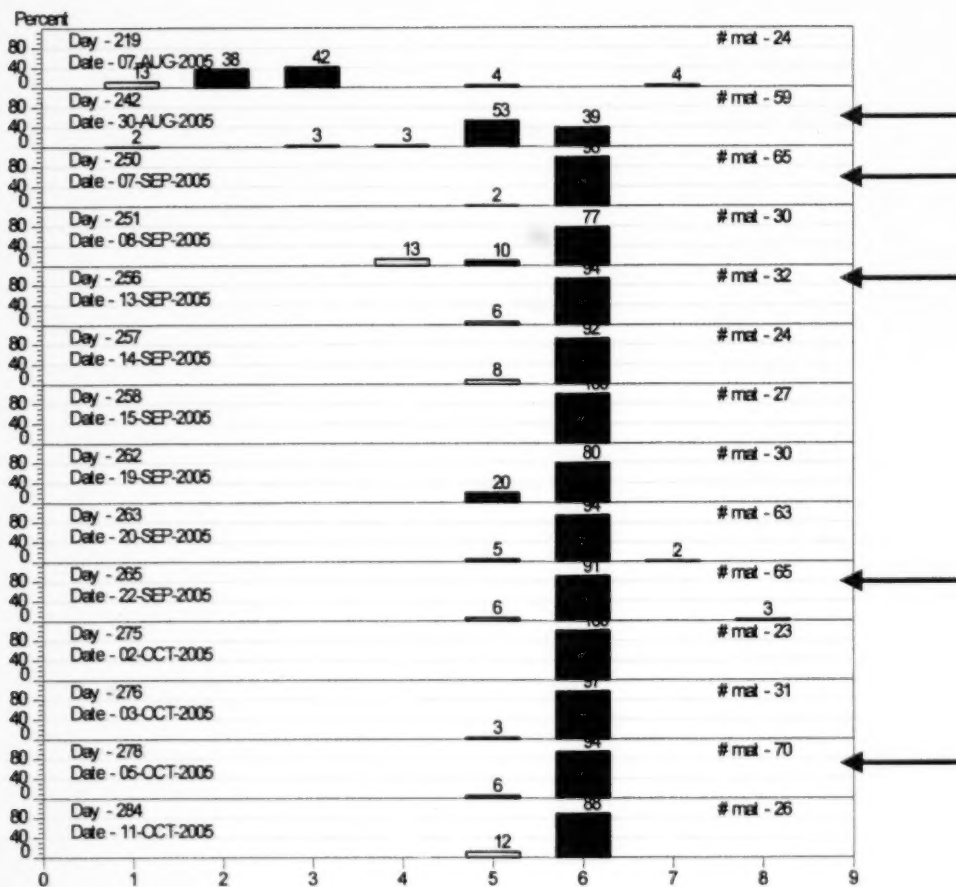


Figure 15. German Bank daily sample maturities. Arrows indicate tagging events.

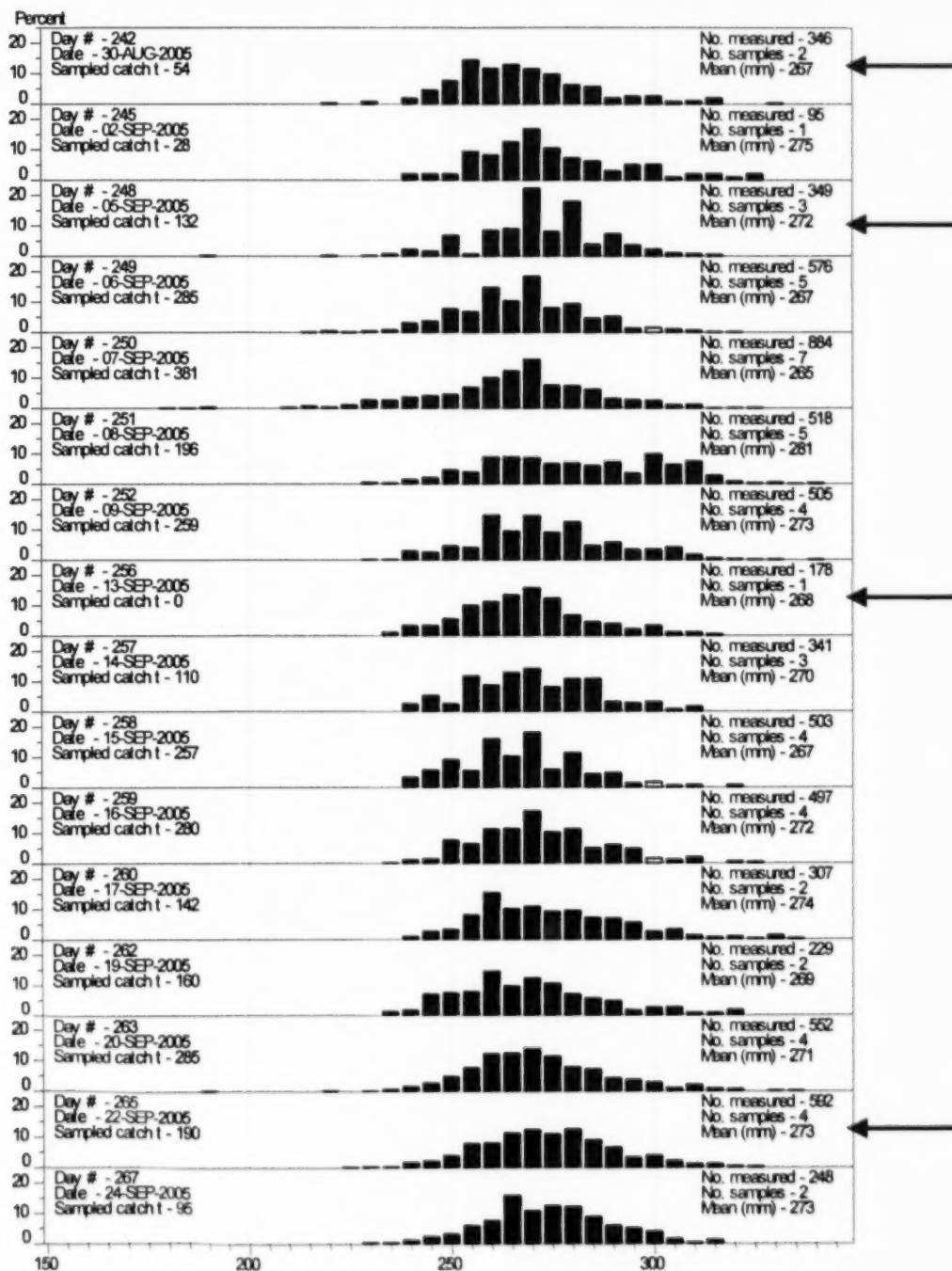


Figure 16. German Bank daily length frequency. Arrows indicate tagging events.

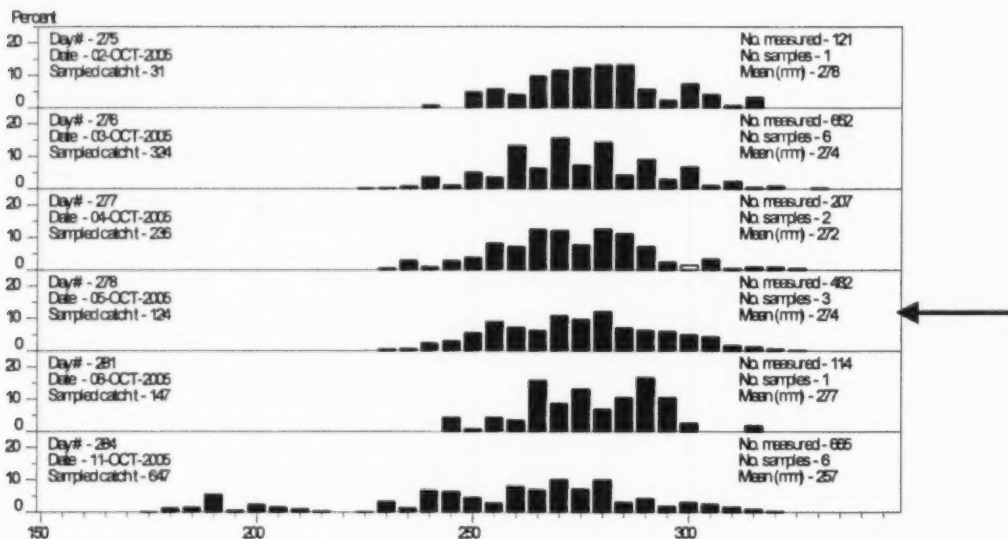


Figure 16 (cont). German Bank daily length frequency. Arrows indicate tagging events.

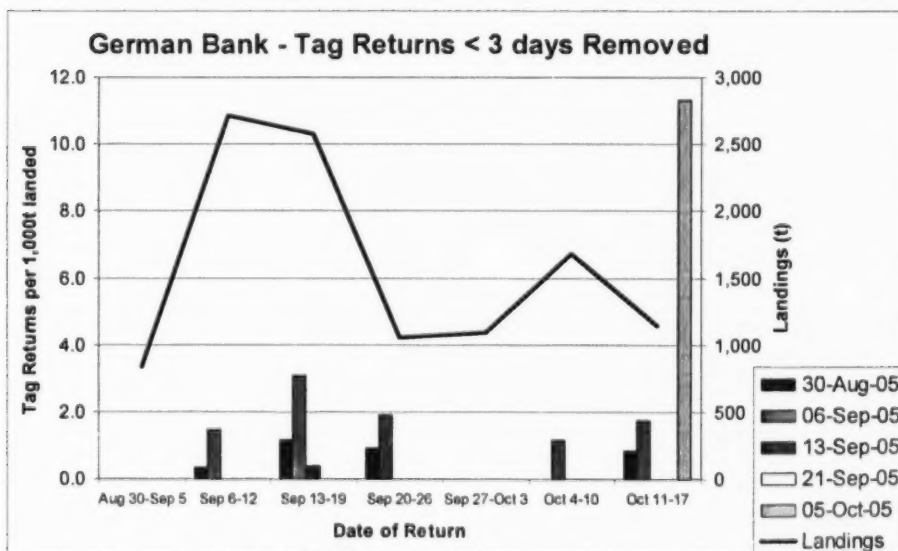


Figure 17. Adjusted tag returns from German Bank by week (data from Table 17 presented graphically). All tags caught < 3 days after tagging were removed

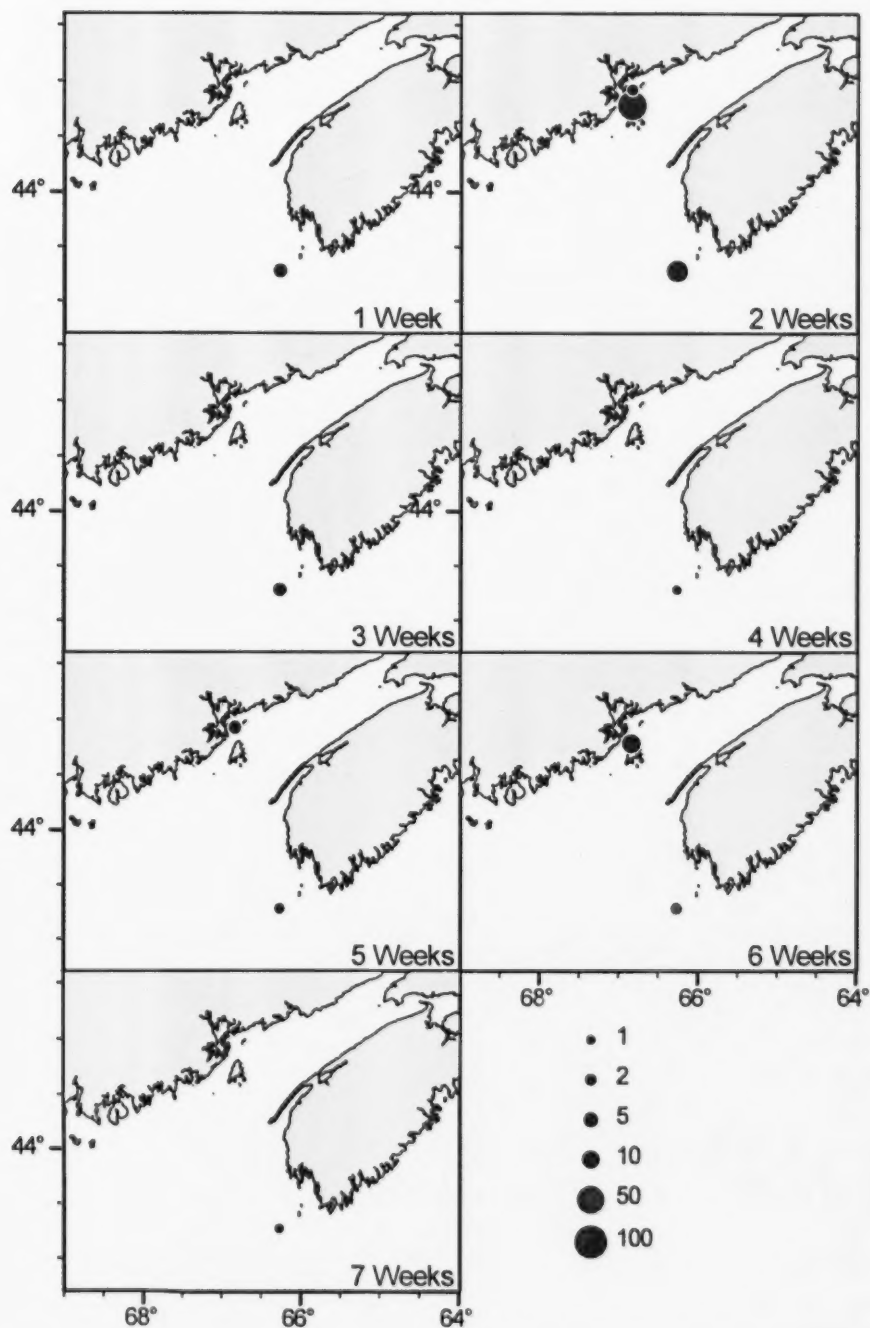


Figure 18. Adjusted tag returns by number of weeks after each tagging event from all areas for fish tagged on German Bank (same data as used in the graph in Figure 17).

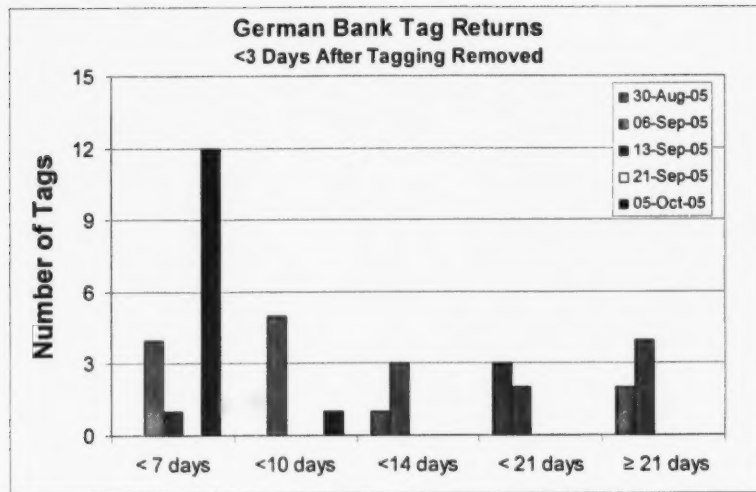


Figure 19. Tag returns from German Bank. All tags caught <3 days after tagging were removed. (Data from Table 19 presented graphically).

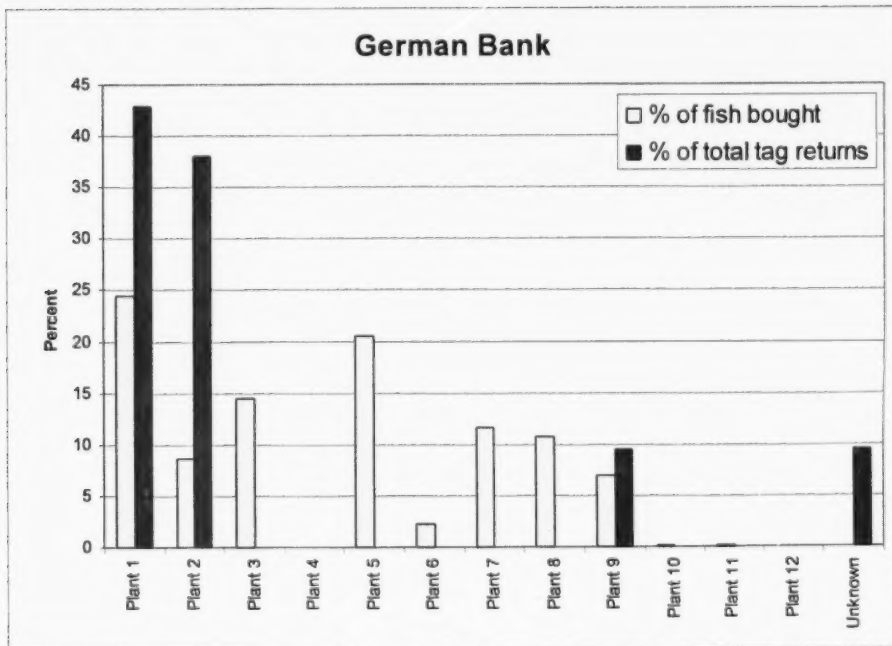


Figure 20: Percent of German Bank fish bought by processor compared to the percent of tag returns received from each plant.